Thermalization in the D1D5 Black Hole

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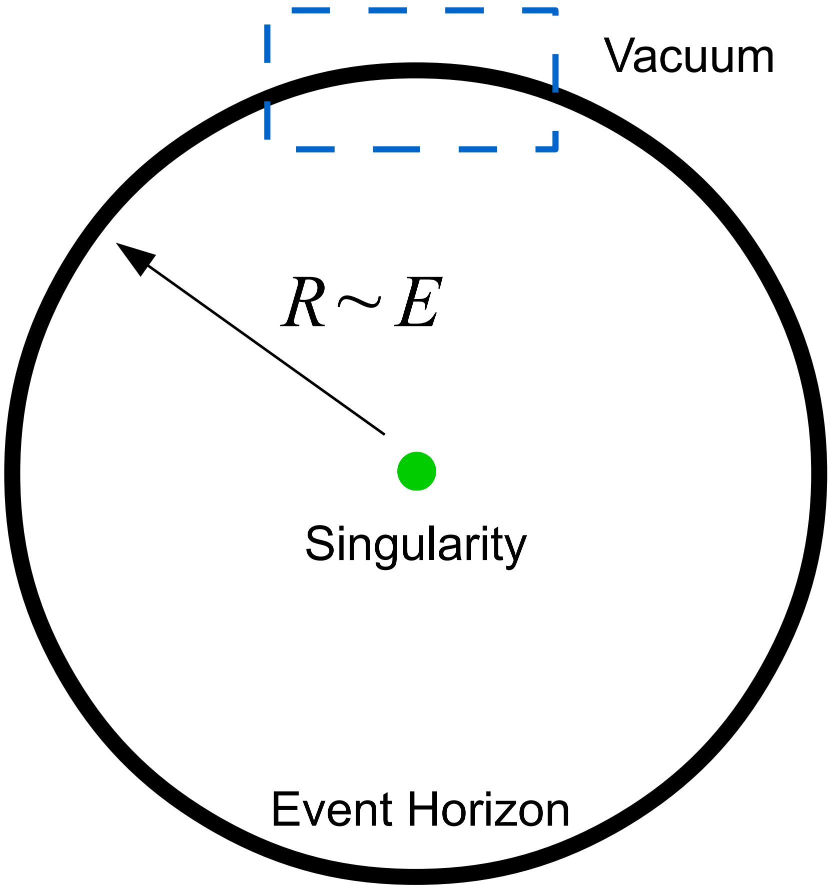
Overview

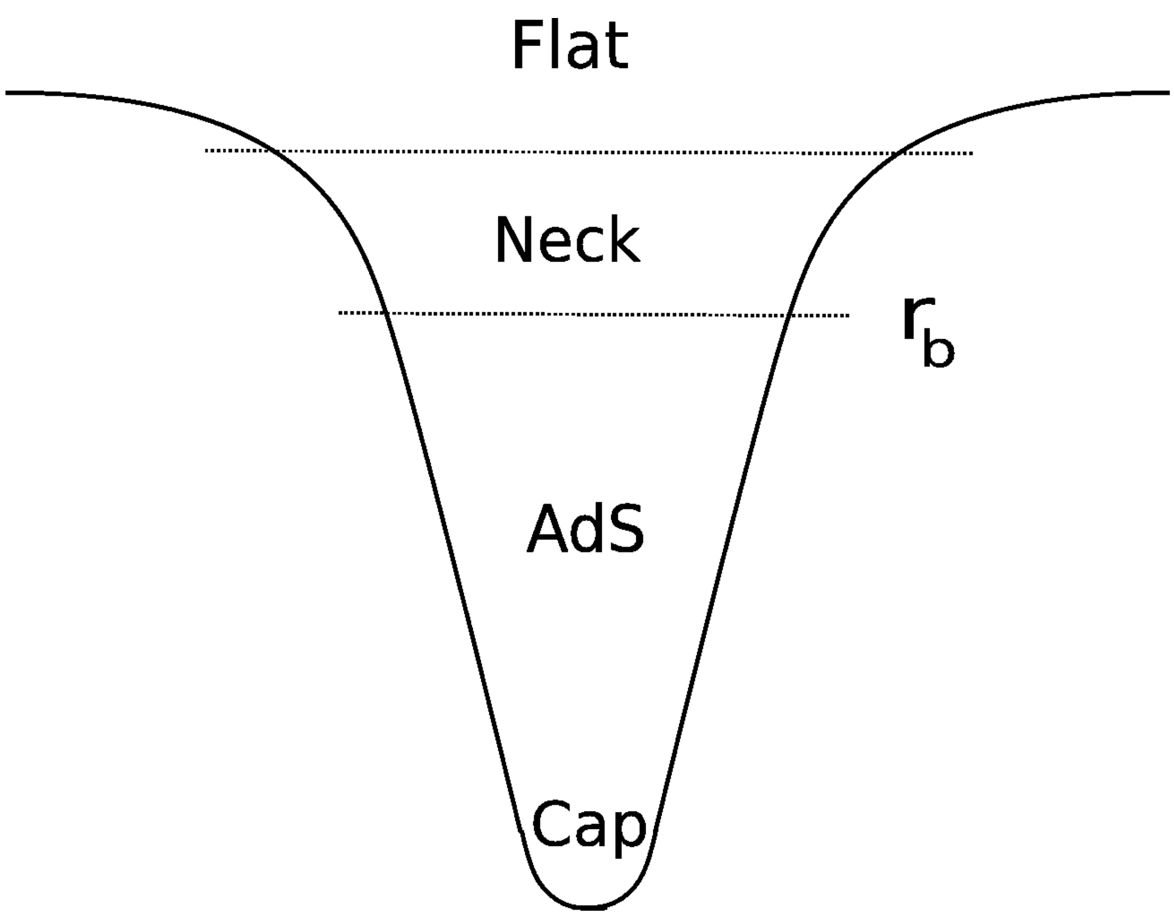
- Classical Black Hole
- The Fuzzball Paradigm
- D1D5 CFT: Orbifold Point
- 1^{st} Order Deformation
- 2^{nd} Order Deformation
- Conclusions

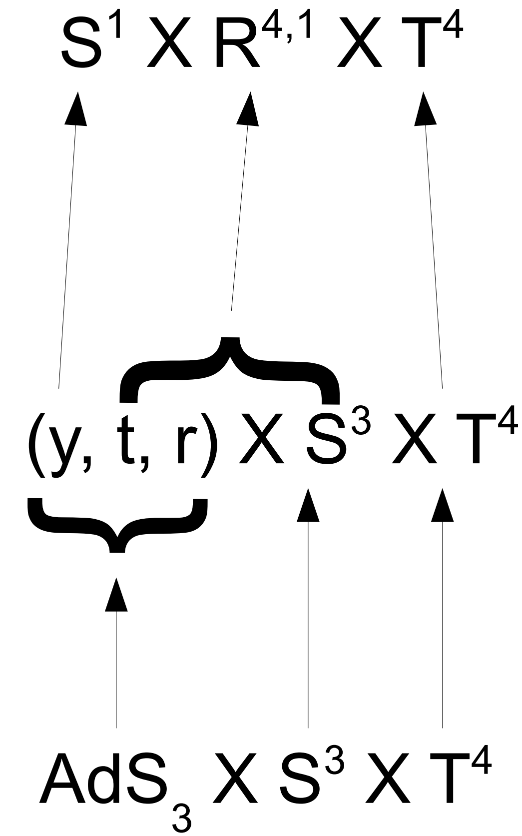
Classical Black Hole

- All matter in singularity
  - Vacuum at horizon
- Entropy
  - $S \sim A$
- Hawking Radiation
  - Pair Production at Horizon
  - Information Paradox



The Fuzzball Paradigm (1)

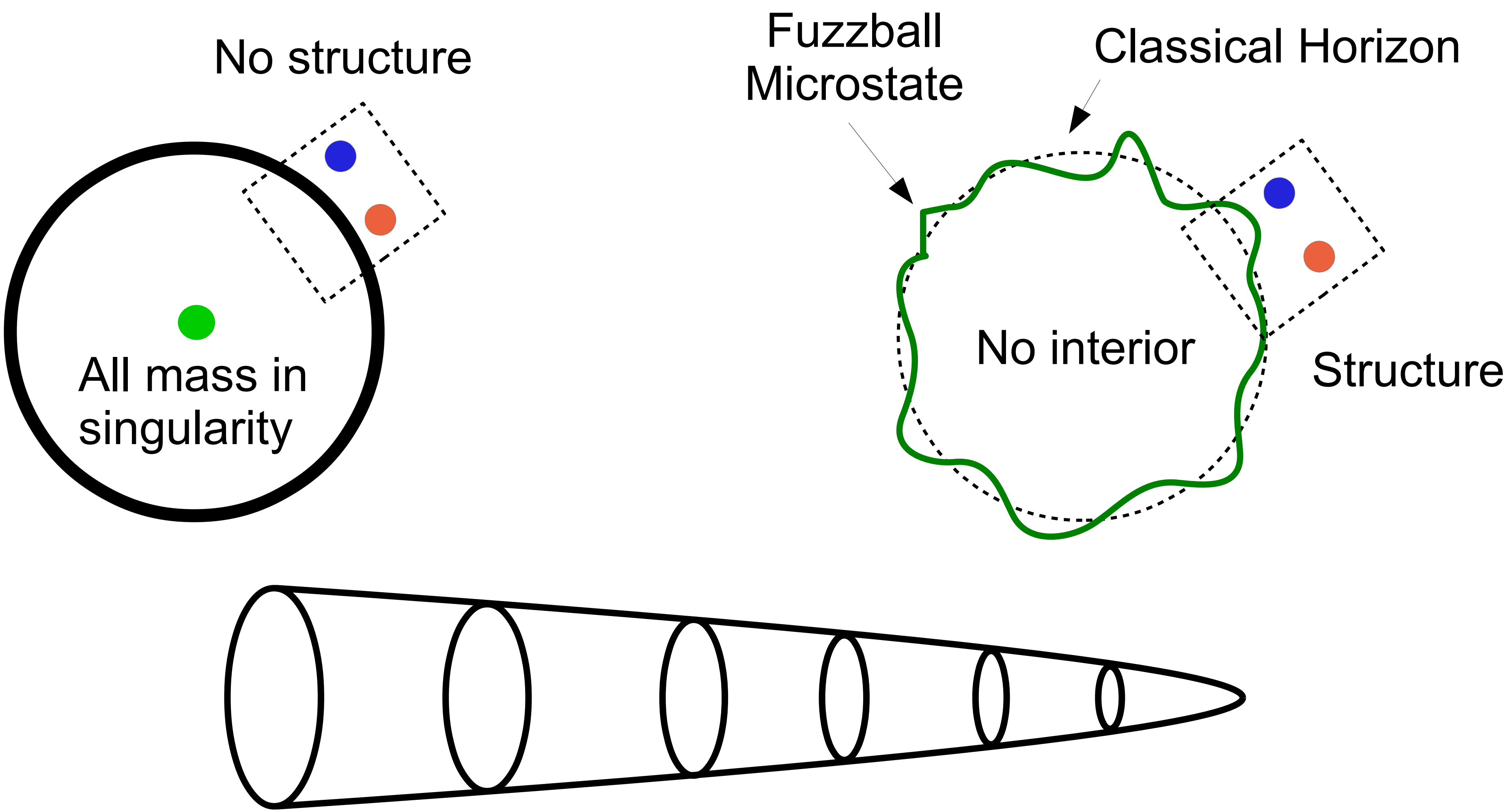




Source: S. G. Avery, B. D. Chowdhury and S. D. Mathur, [arXiv:0906.2015 [hep-th]].

Will make use of CFT dual at r_b

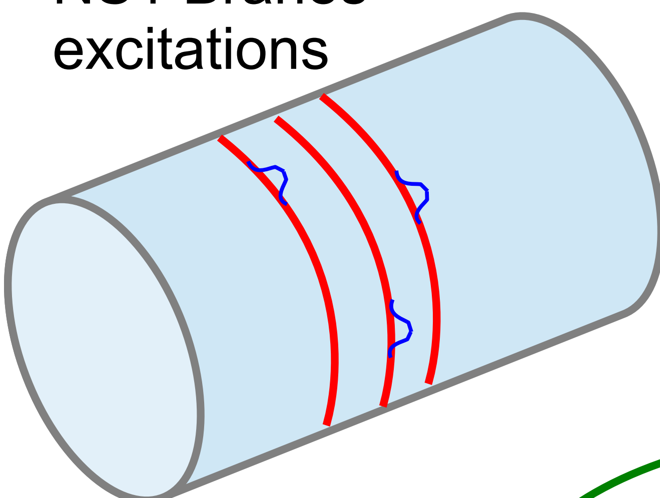
The Fuzzball Paradigm (2)



The Fuzzball Paradigm (3)

NS1-P System

NS1 Branes + excitations



Net momentum P from combination of excitations

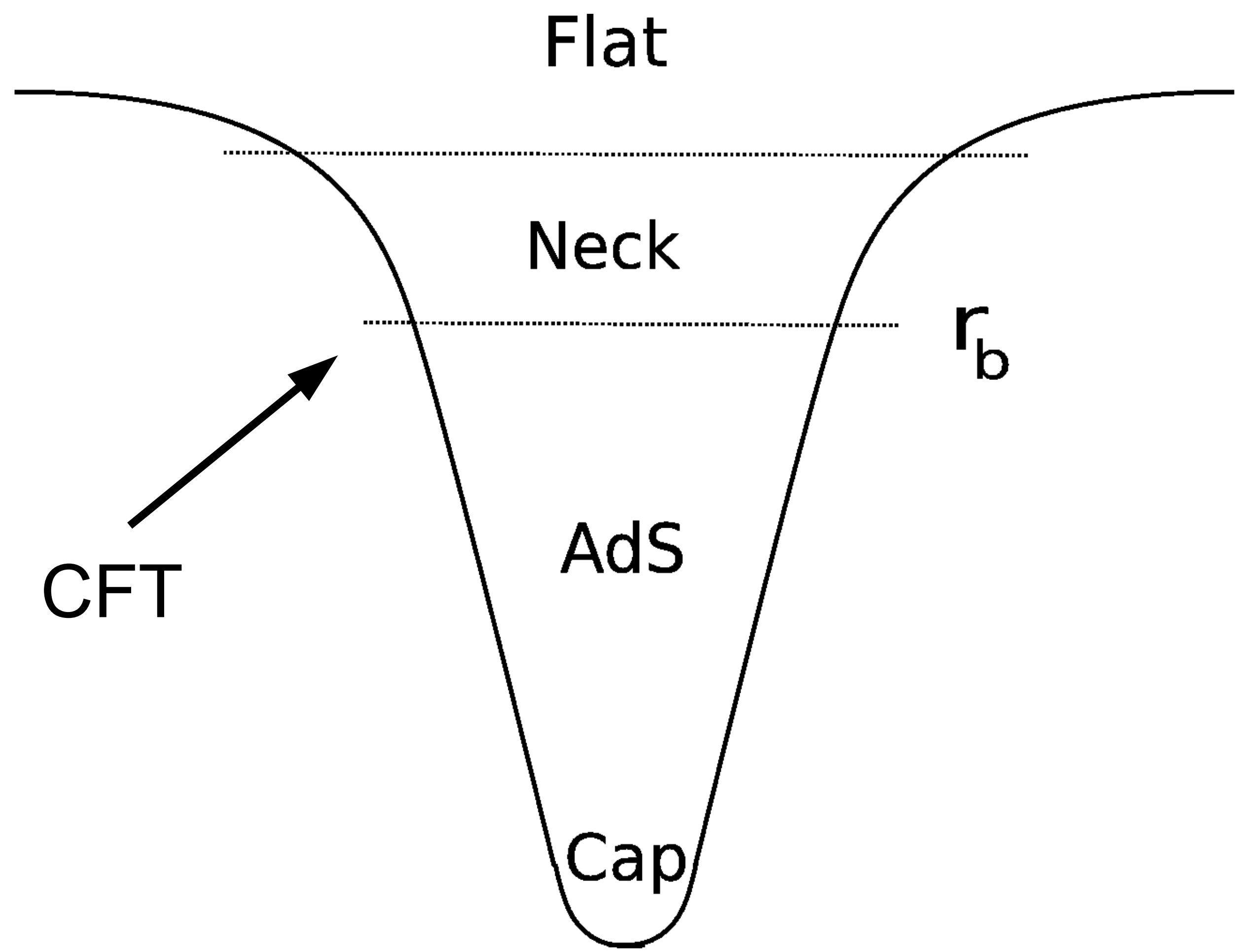
$$N_{Micro} = e^{S_{Bek}}$$

$$S_{Micro} = S_{Bek}$$

Dualities

D1D5 System

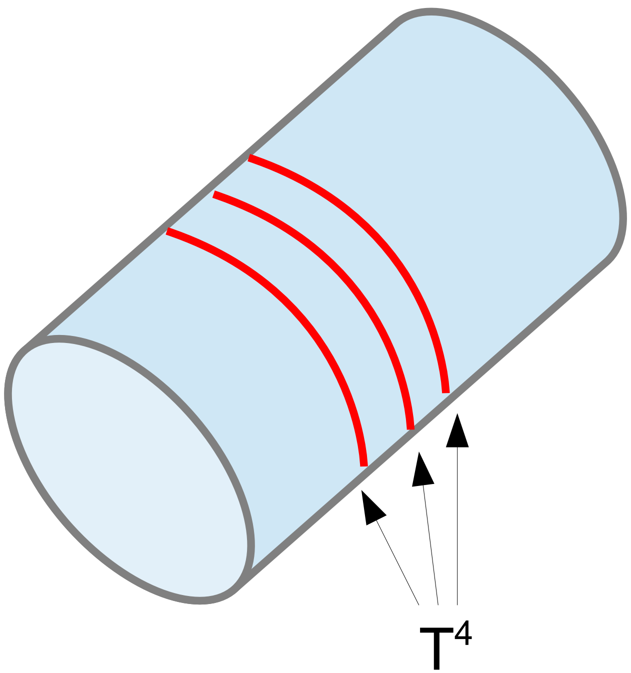
D1D5 CFT: Orbifold Point (1)



Source: S. G. Avery, B. D. Chowdhury and S. D. Mathur, [arXiv:0906.2015 [hep-th]].

D1D5 CFT: Orbifold Point (2)

$$(T^4)^N / S_N$$

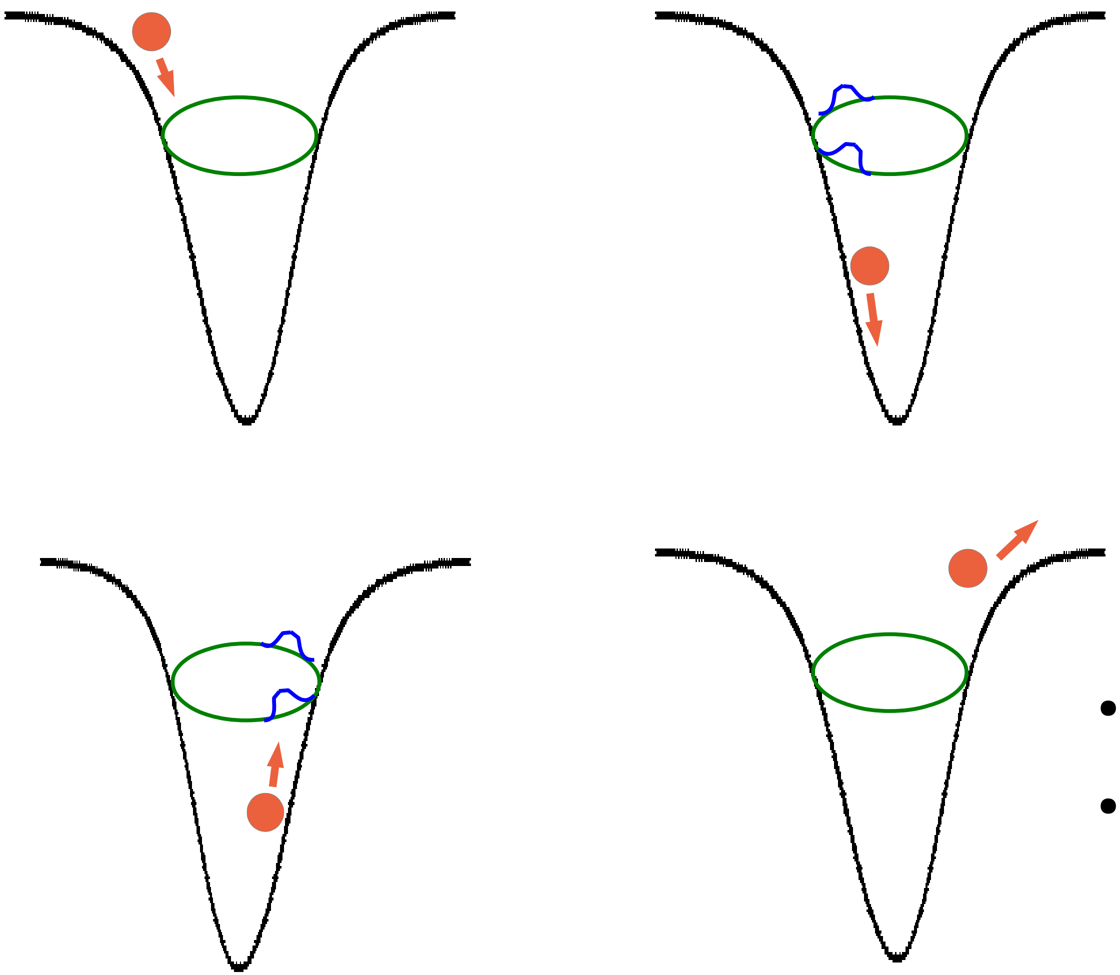


- $n_1 n_5$ copies of a SCFT
- Copies are *symmetrized*
- Non-interacting

$$a_n^{(1)\dagger}|\emptyset\rangle$$

$$(a_n^{(1)\dagger} + a_n^{(2)\dagger})|\emptyset\rangle$$

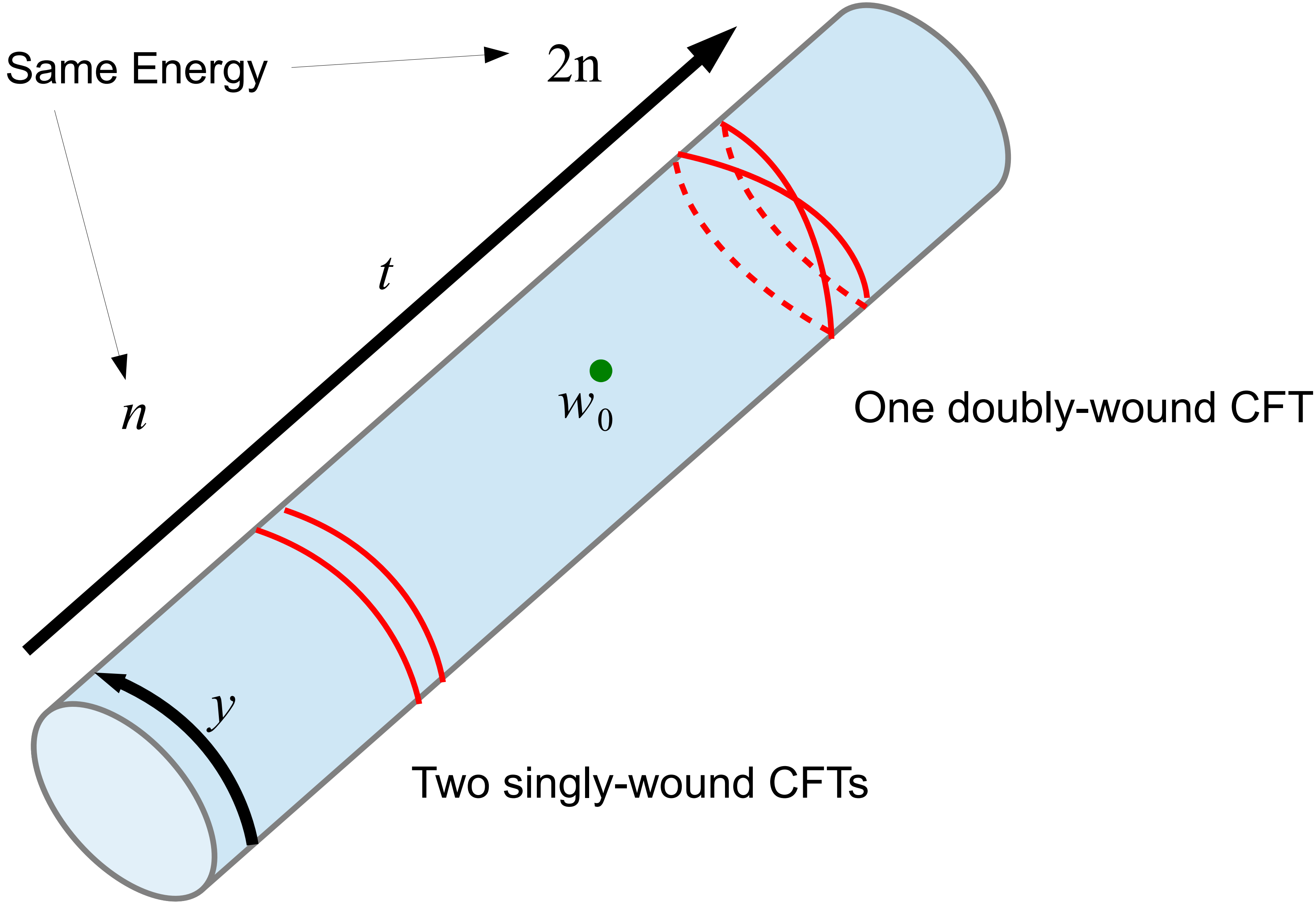
D1D5 CFT: Orbifold Point (3)



$$t_{CFT} = t_{Grav}$$

- Wave packets don't break up
- Same quanta re-emitted

1st Order Deformation (1)



1st Order Deformation (2)

$$\sigma_2^+|0\rangle^{(1)}|0\rangle^{(2)} = |\chi\rangle = \exp\left[\sum_{m,n=1}^{\infty}\gamma^B_{mn}\alpha_{-m}\alpha_{-n}\right]|0\rangle$$

$$\sigma_2^+\alpha^{(i)}_{-n}|0\rangle^{(1)}|0\rangle^{(2)} = \sum_{p=1}^{\infty} f^{B(i)}_{np}\alpha_{-p}|\chi\rangle$$

Fermions too!

1st Order Deformation (3)

$$\gamma^{B}_{mn} \sim \frac{1}{\sqrt{mn}(m+n)}$$

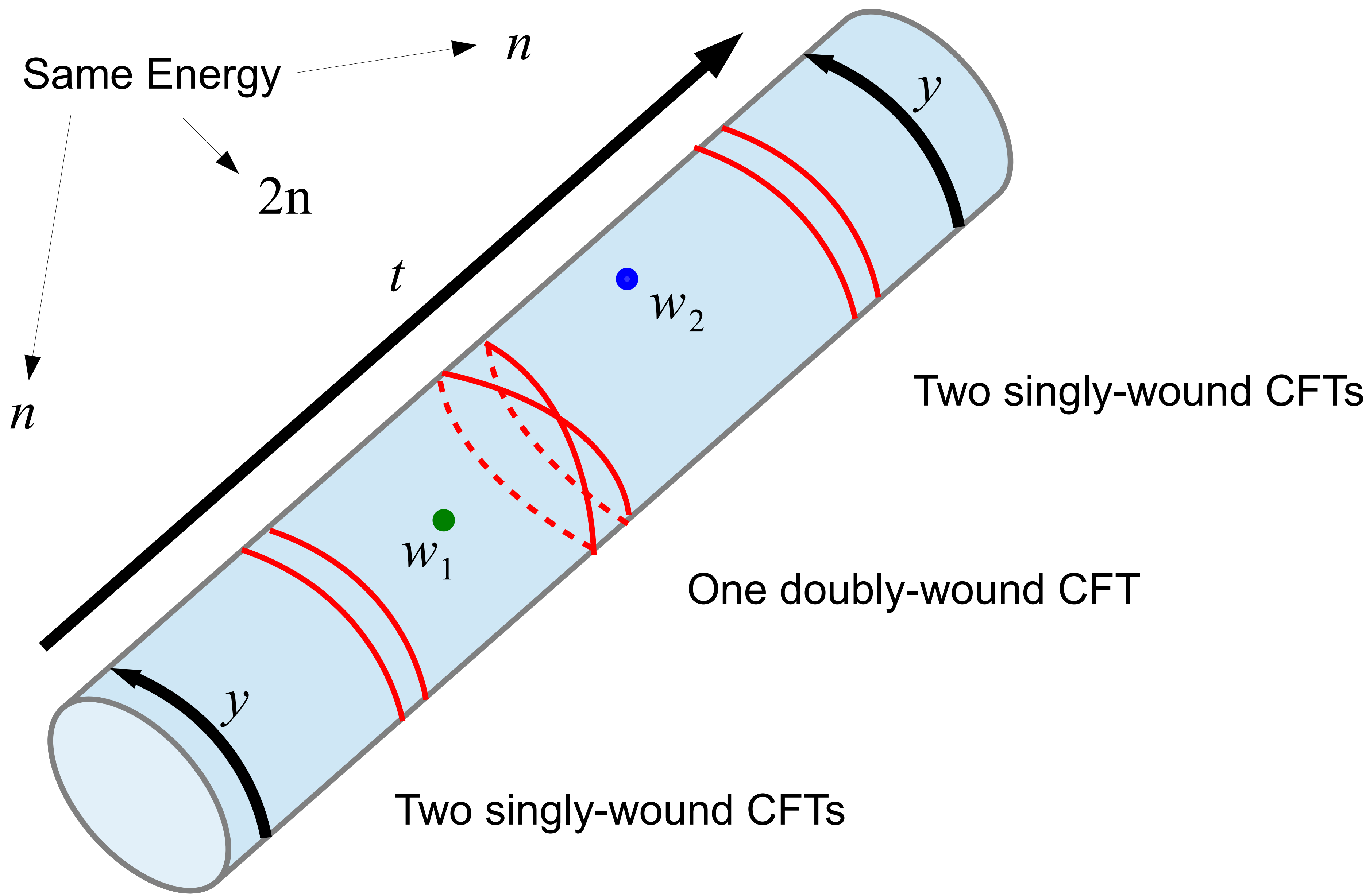
Vanishes for even m or n.

$$f^{B(i)}_{np} \sim \sqrt{\frac{n}{p}}\frac{1}{(2n-p)}$$

½ for p = 2n. Vanishes for other even p.

Peaked near initial energy so wave packet not splitting!

2nd Order Deformation



2^{nd} Order Deformation (2)

$$\sigma_2^+\sigma_2^+|0\rangle^{(1)}|0\rangle^{(2)} = |\chi'\rangle = \exp\left[\sum_{m,n=1}^{\infty}\sum_{(i),(j)=1}^{2}\gamma_{mn}^{B(i)(j)}\alpha_{-m}^{(i)}\alpha_{-n}^{(j)}\right]|0\rangle^{(1)}|0\rangle^{(2)}$$

$$\sigma_2^+\sigma_2^+\alpha_{-n}^{(i)}|0\rangle^{(1)}|0\rangle^{(2)} = \sum_{p=1}^{\infty}\sum_{(j)=1}^{2} f_{np}^{B(i)(j)}\alpha_{-p}^{(j)}|\chi'\rangle$$

Fermions too!

2nd Order Deformation (3)

$$\gamma_{mn}^{B(i)(j)} \sim \frac{1}{\sqrt{mn}(m-n)} g(m, n, \Delta w)$$

Oscillating Function

$$f_{np}^{B(i)(j)} \sim \sqrt{\frac{n}{p}} \frac{1}{(n-p)} h(m, n, \Delta w)$$

Still peaked near initial energy!

Conclusions

- 2nd order results look a lot like 1st order results!
  - Still no wave packet splitting
  - Does this generalize to nth order?
- Exact Solutions very messy
  - Simplifies in continuum limit
  - What are the oscillating functions?
- Where is thermalization?
  - Can wave packets split at any order?
  - Asymmetric untwisting?

References

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